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Cardiopulmonary Resuscitation Support Application on a Smartphone
– Randomized Controlled Trial –

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Background: This simulation trial aimed to compare the quality of cardiopulmonary resuscitation (CPR) with and without the newly-developed CPR support application on smartphones.

Methods and Results: In this trial, participants were randomly assigned to either the CPR support application group or the control group, stratified by sex and previous CPR training. Participants' CPR skills were evaluated by a 2-min case-based scenario test using the Leardal Resusci Anne PC Skillreporting Manikin System®. The outcome measures were the proportion of chest compressions performed in each group and the number of total chest compressions and appropriate chest compressions performed during the 2-min test period. A total of 84 participants were enrolled and completed the protocol. All participants in the CPR support application group performed chest compressions, compared with only 31 (75.6%) in the control group (P<0.001). Among participants who performed chest compressions during the 2-min test period, the number of total chest compressions was significantly higher in the CPR support application group than in the control group (211.6±29.5 vs. 77.0±43.3, P<0.001). The number of appropriate chest compressions tended to be greater in the CPR support application group than in the control group, although it was statistically insignificant (30.3±57.3 vs. 17.2±28.7, P=0.246).

Conclusions: In this cohort of laypersons, the newly-developed CPR support application for smartphones contributed to increasing the implementation rate and the number of total chest compressions performed and may assist in improving the survival rate for out-of-hospital cardiac arrests (UMIN000004740). (*Circ J* 2015; **79:** 1052–1057)

Key Words: Automated external defibrillator; Cardiopulmonary resuscitation; Randomized controlled trial; Smartphones

Sudden cardiac arrest is a leading cause of death in the industrialized world,[1–4] and approximately 70,000 cardiac events occur every year in Japan alone.[5] However, survival after an out-of-hospital cardiac arrest is still <10%.[5–8] Although bystander cardiopulmonary resuscitation (CPR) plays an important key role in the "chain of survival",[1–4] most cardiac arrest victims do not, unfortunately, receive bystander CPR.[6–10] To further increase the proportion of bystander CPR, the dissemination of CPR training is essential, but it is difficult for the general public to acquire and retain CPR skills.[1–4]

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The 2010 CPR guidelines suggest that the use of CPR prompt/feedback devices improves skill acquisition and retention by both the general public and healthcare professionals in

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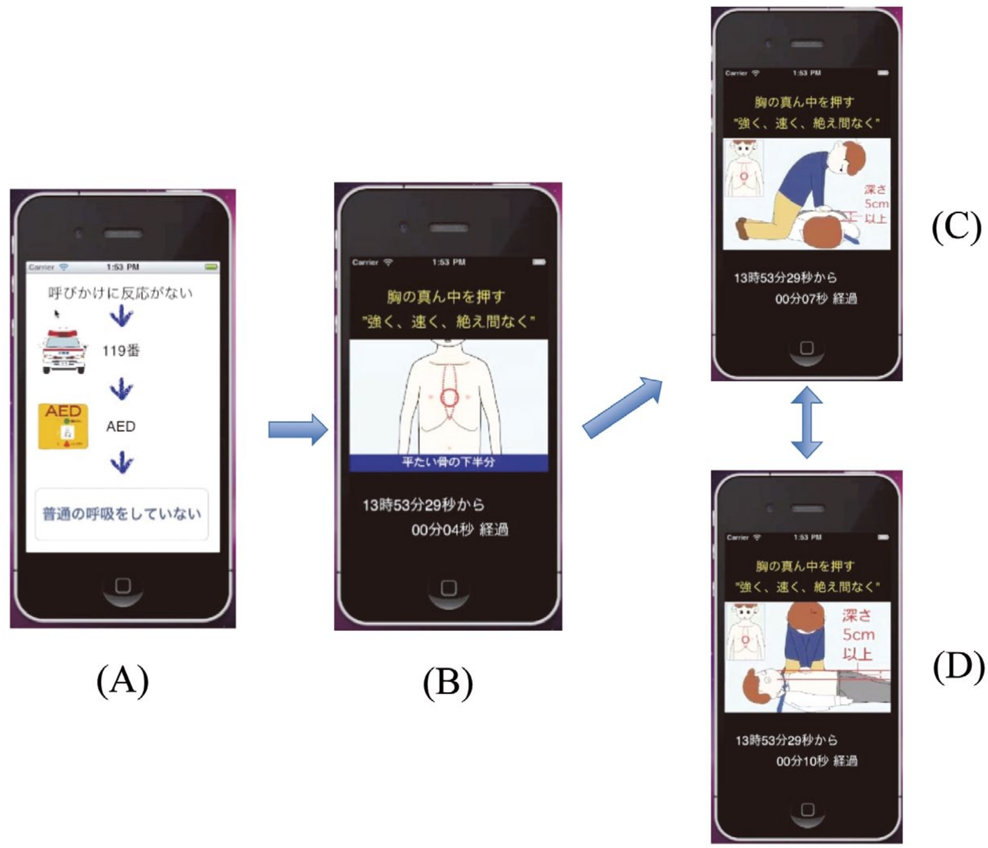

Figure 1. An overview of the smartphone application for cardiopulmonary resuscitation (CPR) support. (**A**) Response check, emergency call to 119 (in Japan) and request for an AED, and breathing check. (**B**) Hand position. Messages read: "Push the center of chest. Push hard, quickly, and without interruption." Progress time from start of CPR is shown at the bottom of the image in (**C**,**D**). Compression depth. Message reads: "At least 5 cm depth." (**B**–**D**) Metronome rhythm of 110 beats/min.

CPR training courses and in the clinical setting.[1–4] Recently, some reports showed that CPR support systems with CPR-guided metronomes[11] and voicemail from mobile phones[12] served to improve CPR quality, and that smartphones with an acceleration sensor as the CPR feedback device were more effective for improving the compression rhythm.[13]

The dissemination of smartphones and tablet devices has been greatly increasing,[14] and their potential use as current CPR prompt/feedback devices might be very important for lay-rescuers.[15–17] Hence, we developed a smartphone application for the general public to assist with CPR. The aim of this simulation trial was to compare the quality of CPR with and without the newly-developed CPR support application on a smartphone.

Methods

Study Design

This study, designed as an open, prospective, individual randomized controlled trial, was carried out in 2011 from January to March.

CPR Support Application on a Smartphone

We developed an application with animation explaining emergency medical services activation, hand position during chest compression, compression depth, and chest compression rate according to metronome-like sounds on a smartphone. This tutorial application was based on the 2010 CPR guidelines,[1–4] and can be used to easily learn and remember CPR visually (**Figure 1**). The metronome rhythm was 110 beats/min in accordance with the 2010 CPR guideline's recommendation.[1–4]

Our application can be used with iPod touches and iPhones. The App Store is a service for the iPhone, iPod Touch, and iPad created by Apple Inc, which allows its users to browse and download applications from the iTunes Store that are developed with the iPhone SDK.

Study Participants

Participants aged ≥18 years were recruited via local billboards and internet advertisements, as well as by word of mouth from current participants. Certified medical professionals such as medical doctors, nurses, pharmacists, nutritionists, medical technicians, radiographers, occupational therapists, physical therapists, medical engineers, paramedics, and students majoring in these medical services were excluded.

Randomization

We held a prior explanatory meeting to obtain informed

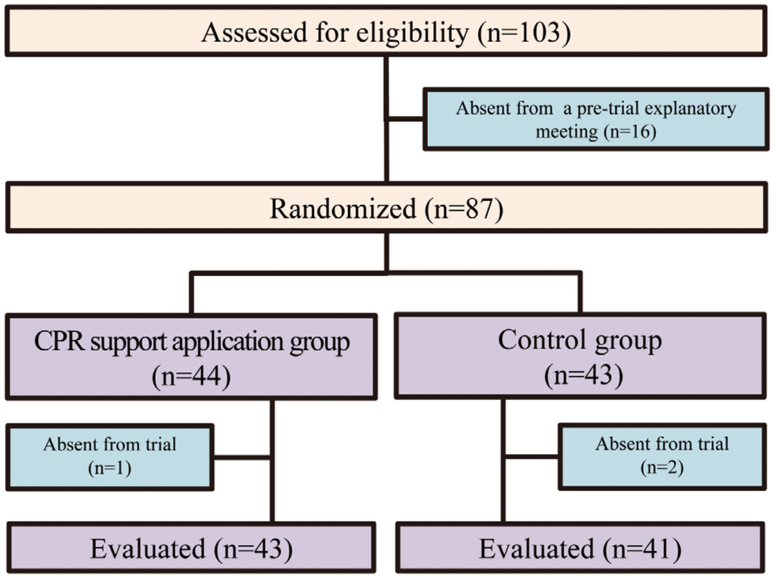

Figure 2. Participant flow in a study of a newly-developed cardiopulmonary resuscitation (CPR) support application on smartphones.

consent and baseline characteristics such as sex, age, and previous CPR training from each participant. Participants were randomly assigned to either the CPR support application group or the control group, stratified by sex (male or female) and previous CPR training (yes or no) using permuted blocks and a computer-generated randomization list drawn up by an independent statistician. The allocation was opened to the participants at the trial site.

Interventions

On the trial day, participants assigned to the CPR support application group carefully familiarized themselves with application on a smartphone for 10 min immediately before the trial. After that, they were encouraged to use the application during the CPR skills test. The control group members attended the CPR skills test without the CPR support application.

The trial was carried out person by person, and each examinee was unaware of the performance of the others. After the trial, the control group members were also instructed on how to use the CPR support application. All participants received a gift card of 3,000 yen as a token of thanks for their participation.

Data Collection

The CPR skills of each participant were evaluated using a case-based scenario at Kyoto University. In this test, each participant was called into the testing room individually and provided with the following scenario: You are in a department store. Suddenly, a man collapses in front of you saying "I feel sick". I (the instructor) am a passing salesclerk. Please do whatever you can do with this manikin in front of you as if it is the collapsed man. After the presentation, we evaluated the participant's CPR skills (including calling for 119 (the emergency call number in Japan) and using an automated external defibrillator (AED)) for 2-min using the Leardal Resusci Anne PC Skillreporting Manikin System® (Laerdal Medical, Stavanger, Norway). The instructor did not do anything other than receive the call for 119 and provide an AED when the participant requested it.

Outcome Measures

The outcome measures were the proportion of chest compressions performed in each group and the total number and appropriateness of the chest compressions performed during the 2-min test period based on the 2010 CPR guidelines.[1–4] Other outcome measures included the proportions calling 119 and requesting an AED, the number of chest compressions with an appropriate depth (≥5 cm), the number of chest compressions with correct hand position, compression depth, time to first resuscitation (the shorter time of initiation of chest compression or ventilation), time to first compression, and time without chest compression.

Statistical Analysis

The sample size was calculated based on the number of appropriate chest compressions performed for 2 min in previous studies.[12,18] The mean number of appropriate chest compressions performed for 2 min was approximately 48,[18] and the CPR support device using voicemail improved CPR quality by approximately 30%.[12] Based on these results, we estimated that a user of the CPR support application would perform 64 chest compressions, and a control group member would perform 48 chest compressions. Based on 0.8 power to detect a significant difference ($P=0.05$, two-sided), 40 participants were required for each study group. To compensate for possible absences, we planned to enroll 45 participants per group.

Baseline characteristics and outcomes were compared between groups using an unpaired t-test for numerical variables and chi-square test for categorical variables. Data are presented as mean±standard deviation. In addition, we divided the subjects into 2 groups: trained and untrained CPR groups (according to a previous study[12]). All of the tests were 2-tailed and $P<0.05$ was considered statistically significant. All statistical analyses were performed using SPSS statistical package version 18.0J (SPSS, Inc, Chicago, IL, USA).

Ethical Considerations

All procedures were conducted according to the Declaration of Helsinki. Participants gave written informed consent prior

Table 1. Baseline Characteristics of Participants in a Study of a Newly-Developed CPR Support Application on Smartphones

	CPR support application group (n=43)	Control group (n=41)	P value
Age, years, mean ± SD	21.3±2.0	21.6±2.6	0.511
Men, n (%)	31 (75.6)	32 (74.4)	1.000
Previous CPR training, n (%)	27 (62.8)	25 (61.0)	1.000
Experience with sudden cardiac arrest, n (%)	2 (4.7)	1 (2.4)	1.000
Family history of sudden cardiac arrest, n (%)	1 (2.3)	1 (2.4)	1.000
Having a smartphone, n (%)	11 (25.6)	13 (31.7)	0.631

CPR, cardiopulmonary resuscitation; SD, standard deviation.

Table 2. CPR Skills of the Participants in a Study of a Newly-Developed Support Application on Smartphones

	CPR support application group (n=43)	Control group (n=41)	P value
Activation of EMS, n (%)			
Call 119 (in Japan)	29 (67.4)	19 (46.3)	0.041
Call for an AED	26 (60.5)	9 (22.0)	<0.001
Chest compressions performed, n (%)	43 (100.0)	31 (75.6)	<0.001
Chest compressions during 2-min test period, n, mean ± SD*			
Total chest compressions	211.6±29.5	77.0±43.3	<0.001
Appropriate chest compressions	30.3±57.3	17.2±28.7	0.246
Chest compressions with correct hand position	109.0±92.9	42.6±35.5	<0.001
Chest compressions with appropriate depth	65.7±73.4	41.0±48.7	0.095
Compression depth (mm)	35.0±9.2	36.7±12.3	0.492
Resuscitation time course (s), mean ± SD			
Time to first chest compression or first ventilation	37.1±17.9	29.3±13.8	0.048
Time to chest compression	37.1±17.9	31.4±14.9	0.154
Time without chest compression	4.4±11.7	63.8±23.1	<0.001

*Calculated only for those who performed chest compressions (n=43 in the CPR support application group and n=31 in the control group). AED, automated external defibrillation; EMS, emergency medical service. Other abbreviations as in Table 1.

to participation. This study was approved by the Ethics Committee of Kyoto University Graduate School of Medicine, and was registered in the UMIN Clinical Trials Registry (UMIN000004740).

Results

A total of 103 participants applied, but 16 did not attend the pre-trial explanatory meeting and so we did not obtain their informed consent. The remaining 87 were randomly assigned to either the CPR support application group (44) or the control group (43); 1 participant from the CPR support application group and 2 from the control group did not attend the trial, leaving 43 in the CPR support application group and 41 in the control group who completed the study protocol (**Figure 2**).

Baseline characteristics of the participants are shown in **Table 1**. The mean age was 21 years in both groups, and there were no significant differences between the groups in sex ratio, previous CPR training, experience of sudden cardiac arrest, family history of sudden cardiac death, or having a smartphone.

CPR skills in the CPR support application group and control group are shown in **Table 2**. The proportion of those who called 119 and requested an AED was significantly greater in the CPR support application group than in the control group (67.4% vs. 46.3%, P=0.041, and 60.5% vs. 22.0%, P<0.001, respectively). All participants in the CPR support application group performed chest compressions, compared with only 31 (75.6%) in the control group (P<0.001). Among participants who performed chest compressions during the 2-min test period, the number of total chest compressions was significantly higher in the CPR support application group than in the control group (211.6±29.5 vs. 77.0±43.3, P<0.001). Consequently, the mean time without chest compressions was significantly shorter in the CPR support application group than in the control group (4.4±11.7 s vs. 63.8±23.1 s, P<0.001). The number of appropriate chest compressions tended to be greater in the CPR support application group than in the control group, although it was statistically insignificant (30.3±57.3 vs. 17.2±28.7, P=0.246). The number of chest compressions with correct hand position were significantly higher in the CPR support application group than in the control group (109.0±92.9 vs. 42.6±35.5, P<0.001), and the number of chest compressions with appropriate depth tended to be higher in the CPR support application group than in the control group, although it was statistically insignificant (65.7±73.4 vs. 41.0±48.7, P=0.095). The mean time to first chest compression or first ventilation was significantly longer in the CPR support application group than in the control group (37.1±17.9 s vs.

Table 3. Resuscitation Skills of the Participants in a Study of a Newly-Developed Support Application on Smartphones According to Prior Training in CPR

	CPR trained			Not CPR trained		
	CPR support application group (n=27)	Control group (n=25)	P value	CPR support application group (n=16)	Control group (n=16)	P value
Activation of EMS, n (%)						
Call 119 (in Japan)	20 (74.1)	14 (56.0)	0.141	9 (56.2)	5 (31.2)	0.143
Call for AED	18 (66.7)	6 (24.0)	0.002	8 (50.0)	3 (18.8)	0.068
Chest compressions performed, n (%)	27 (100.0)	20 (80.0)	0.020	16 (100.0)	11 (68.8)	0.043
Chest compressions during 2-min test period, n, mean±SD*						
Total chest compressions	211.0±33.9	91.6±44.1	<0.001	212.8±21.1	50.6±27.4	<0.001
Appropriate chest compressions	39.5±64.4	17.4±31.0	0.163	14.6±39.9	16.8±25.3	0.874
Chest compressions with correct hand position	119.2±89.4	46.2±42.3	0.002	91.8±99.0	36.1±17.1	0.078
Chest compressions with appropriate depth	70.3±74.2	49.5±53.1	0.291	57.9±73.8	22.9±35.7	0.158
Compression depth (mm)	36.2±9.0	39.5±9.8	0.237	32.9±9.4	31.6±15.2	0.785
Resuscitation time course (s), mean±SD						
Time to first chest compression or first ventilation	39.9±18.3	32.0±14.2	0.114	32.3±16.8	24.6±12.1	0.201
Time to chest compression	39.9±18.3	33.5±15.6	0.215	32.3±16.8	27.6±13.2	0.438
Time without chest compression	5.7±14.6	60.7±22.6	<0.001	2.2±2.7	69.4±24.0	<0.001

*Calculated only for those who performed chest compressions. Abbreviations as in Tables 1,2.

29.3±13.8s, P=0.048).

The CPR skills in the groups with and without previous CPR training are shown in **Table 3**. Among the CPR-trained participants, all performed chest compressions in the CPR support application group, against 20 (80%) in the control group (P=0.020). Among the CPR-trained group, the number of appropriate chest compressions tended to be approximately 2-fold greater in the CPR support application group than in the control group, although it was statistically insignificant (39.5±64.4 vs. 17.4±31.0, P=0.163). In the CPR support application group, both the proportion requesting an AED and the number of total chest compressions was significantly higher, and time without chest compressions was significantly shorter than in the control group, irrespective previous CPR training.

Discussion

We developed an application for smartphones to assist bystanders with performing CPR, and evaluated its efficacy in a randomized controlled trial. We demonstrated that the smartphone CPR support application contributed to increasing the implementation rate and the total number of chest compressions. Thus, the CPR support application, which is easily available for CPR training, should be of help in resuscitation science.

In this study, all participants in the CPR support application group performed chest compressions, but only 75% in the control group did, and the calling for 119 and requesting an AED was also significantly higher in the CPR support application group than in the control group. These results were consistent with previous reports on the acceleration of emergency activation by video-learning.[19,20] It is most difficult for bystanders in real emergency settings to perform CPR for a collapsed person,[1–4] and our application explaining the "chain of survival" (ie, the emergency call, CPR, and defibrillation) would be important in giving bystanders confidence to assist the victim. In addition, the total number of chest compressions was higher and the interruption time was shorter in the CPR support application group than in control group. Previous reports showed that voicemail and video delivered by cellular phones improved the quality of CPR,[12,21] but the issue of what type of delivery device would be most effective is still controversial. We consider that smartphones are widely available in the industrialized world, and that CPR application will play a key role in the public acquiring and retaining CPR skills.[22]

This study also evaluated CPR quality in terms of hand position and compression depth based on the 2010 CPR guidelines,[1–4] but the number of appropriate chest compressions was insufficient regardless of whether or not the CPR support application was used. This result suggests that it is difficult for the general public to perform high-quality CPR, especially actual emergency settings.[1–4] To increase the quality of the CPR performed by bystanders, it is most important for the general public to receive CPR training.[23]

In addition, the time to first CPR was longer in the CPR support group than in the control group. This result was consistent with previous reports; it took longer to start CPR by the prompt/feedback device users because of the device's boot time.[12,21,24] Further efforts to improve the application are indispensable for its utility and effectiveness.

In the subgroup analysis, the number of appropriate chest compressions was insufficient in both groups, irrespective of previous CPR training. However, the number of appropriate chest compressions among those in the CPR-trained group tended to be higher in the CPR support application group than in the control group, suggesting that the CPR support application might have produced a retention effect for those who had received previous CPR training. Participants in this study were using our application for the first time, so greater familiarity with this application might be effective in the general public acquiring the skills to perform high-quality CPR.

The number of smartphones is increasing year-by-year, reaching approximately 10 million units in Japan.[14] Therefore, smartphones and tablet devices will become key instruments in resuscitation education, as well as at the actual emergency scene. The dissemination of the CPR support application to these devices might improve the general public's understanding of the importance of CPR and using an AED, and lead to an increase in the proportion of bystander CPR.

Study Limitations

The resuscitation skills were evaluated by a case-based scenario test, and so resuscitation performance in a real emergency setting where lay-rescuers might easily panic was unknown.[23] Moreover, appropriate resuscitation skills on a manikin might not necessarily lead to better clinical outcomes. Thus, we consider that further improvements of this application are warranted to make it an even better CPR support device that can be used in the actual resuscitation scenes. In addition, our results might not be fully generalized because many of the study participants were young adults. Therefore, validation for the middle-aged is also needed.

Conclusions

A newly-developed CPR support application on smartphones contributed to increasing the implementation rate and the number of chest compressions among a cohort of the general public. Further improvement of this application is needed for its effective use in resuscitation education and at the actual emergency scene.

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